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# GROWING AND HANDLING ASPARAGUS CROWNS

BY

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At present California stands preëminent in asparagus production. The most concentrated asparagus-growing area is located in the Delta region, including the “reclaimed” low lands of the lower Sacramento and San Joaquin rivers. The Imperial Valley has also grown a considerable acreage of asparagus for a number of years, from which early shipments are made to the Middle West and the Eastern markets. Small acreages are to be found in other sections of the state. Most of the asparagus is grown, however, in the hot interior valleys like the Sacramento, San Joaquin, Imperial, and San Fernando, because along the coast the lower average temperatures make asparagus production unprofitable.

Asparagus growing has increased generally over the entire country during the last few years, but in California the increase in acreage has been greater than in any other state. The present indications are that the acreage will continue to increase for a number of years, especially in those sections where the crop is grown for canning purposes. It will be necessary to grow sufficient crowns to plant this additional acreage and also to replace the old plantations that are plowed up each year because of ageing. The profitable life of an asparagus bed in the Delta region is about twelve years. In some sections it appears to be somewhat longer, but if the acreage is to be maintained, approximately one twelfth of it must be replanted each year.

This bulletin contains a number of contributions to our knowledge of the growth habits of asparagus which bear upon the production and handling of crowns. Other material more or less generally known to experienced asparagus growers is included in order to make the bulletin of more service to those who have had little or no experience in the growing and handling of crowns.

#### GROWING VERSUS BUYING CROWNS

Commercial asparagus growers generally grow their own one year old crowns. There are several reasons for doing this: (1) *It usually costs less to grow crowns than to buy them.* This applies especially to large acreages such as are usual when asparagus is grown for canning or as a truck crop. Freight charges are high on the most desirable crowns which are bulky and heavy. (2) *The grower has information regarding the seed.* When he produces his own seed, he is familiar with the variety and performance of the beds from which the seed has been obtained. Seed for planting the nursery may be obtained from reliable sources, either firms, or individuals, who know the principles of selection and give special attention to the improvement of this crop. Since the yields from asparagus extend over a period of ten or twelve years, extra effort can well be expended in securing the best seed. Using cheap seed is not economy. (3) *There is opportunity for rigorous crown selection.* Even under conditions conducive to the best crown development some grading should be made. Consequently, it is necessary to grow a surplus so that there will be a sufficient number of good crowns for planting. Some nurserymen and seedsmen sell only the best crowns, but as a general rule they do very little grading. (4) *Delayed planting can be avoided.* The best results are obtained, as regards immediate growth

and perfect stand, if the crowns are set shortly after digging. (5) *Climatic conditions in California are conducive to good crown development.* On account of the long growing season and the great amount of sunshine prevalent during the spring, summer and early fall, plants make a greater growth in one season in California than in most parts of the country. For these reasons it is deemed highly desirable that growers raise their own crowns.

If only a few crowns are to be planted as in the case of the home garden, it is usually cheaper to buy them from a reliable nurseryman. The buyer should specify that only well-developed one-year-old crowns will be accepted.

#### TYPES OF SOIL

Good asparagus crowns can be grown on soils of various types. The best soils, however, for the production of nursery stock are well-decomposed peat, or light, sandy loam. These soils are open and porous and facilitate root penetration and elongation. One of the most important reasons for choosing light soils for the nursery is that crowns may be dug with a minimum of injury. Excellent crowns can be produced on light sandy soils if fertilizers and a sufficient amount of water are applied.

Heavy soils can be used for the growing of crowns, but they are not so desirable as the lighter types. A great amount of labor is required to keep such soils in good physical condition. They usually remain wet till late spring, especially in regions of heavy winter rainfall, and they warm up more slowly than the lighter soils, thus delaying germination and retarding the growth of the plant after germination. Since heavy soils become packed, it is difficult to dig the crowns without injuring many of the rootstocks and losing a large percentage of the fleshy roots. As these roots contain the reserve food supply, their loss is bound to weaken the early growth of the plant.

#### PREPARATION OF THE SEED BED

Land that is sub-irrigated should be practically level so that uniform moisture conditions can be maintained. On surface irrigated land a slight fall is necessary. The land should be comparatively free from clods. A fine, well pulverized seed bed permits the soil particles to come into close contact with the seed, insuring a constant water supply and rapid germination.

It is well known that asparagus seed germinates slowly. Consequently, weeds often make sufficient growth to hide the young aspara-

gus plants before they are large enough to be seen in the row and cultivated. A weedy asparagus nursery requires much labor and expense and may result in inferior crowns. Special care should be taken to select land that is comparatively free from weeds.

### SEED SELECTION

It is well recognized by all asparagus growers that large, plump, glossy and fully matured seed is superior to small, shriveled, dull and immature seed. However, the methods of growing asparagus seed of high quality have not been given the attention that they deserve.

*Age of Plant from which to Select Seed.*—There is a diversity of opinion among growers as to what the ages of plants should be in order to yield seed of the best quality. The statement is made by some that plants must be “not less than four years old” before they have sufficient maturity and vigor to produce seed of high quality. Other growers state that seed should be harvested only from plants, the crowns of which were planted the previous year. The reason given for the latter advice is that plants of this age have not been “weakened” by the harvesting of sprouts during the current year to the extent that older plants have, and “consequently it has been possible for more energy to be directed to the production of seed.” In explanation of this claim, it should be stated that it is a common practice on California asparagus farms to cut market asparagus for a period of about three or four weeks the first year after transplanting; whereas, in older beds, the cutting season is for a much longer period. Hence, in the former case, there is a longer season of growth after the cutting period than in the older beds. It is reasoned that seed from plants which have been cut for a few weeks only will have a better opportunity to fill out and mature.

It should be stated also that by taking seed from young asparagus beds, rather than from old ones, the grower has a better opportunity to make rapid improvement in his varieties.

Other growers claim that there is no correlation between the age of the mother plant, and the vigor of the seed it produces.

Unfortunately, there are no reliable experimental data which will enable us to discuss authoritatively the three views presented above and to make a definite recommendation as to the best age of plants from which to select seed.

*Quality of Seed from Different Parts of the Plant.*—Some hold the opinion that seed borne on different parts of the same plant varies in quality. It is stated that the best seed is procured from

the lower part of the plant and that consequently it is advisable to top the plant by removing from eight to twelve inches after the basal flowers have been fertilized. The first flowers to open and the first berries to form are on the main shoot near the base of the plant; and considering the whole plant, or any one branch, the order of maturing of berries is from the base to the apex. At the tips of the branches, then, there may be at harvest time a considerable number of berries which are not so well developed as those farther down on the branches, and consequently the harvested seed may contain a certain percentage of seed from relatively immature berries. It is believed that this condition can be obviated by cutting back the tops after the basal flowers have been fertilized. It is also asserted that topping the plants leaves more nourishment available for the remaining seeds, and that they will thereby become larger and produce more vigorous seedlings.

Since no carefully conducted tests have been made to ascertain the value of the practice of cutting back the tops of seed-bearing plants, the authors are not in a position either to recommend or discourage this practice. It appears, however, that careful screening and grading will eliminate the smaller and less mature seeds, which are borne near the tops of the branches. Grading is suggested as being a possible and desirable substitute for topping.

*Selecting and Handling Plants for Seed Production.*—The commercial grower who is producing his own seed, should observe some of the fundamental principles of selection. With most of our crops, both male and female reproductive organs occur on the same plant and usually in the same flower, but each asparagus plant is of one sex only. That is, any one asparagus plant will produce either pollen-bearing flowers only or seed-bearing flowers only. We speak of pollen-bearing plants as *male* or *staminate* and seed-bearing plants as *female* or *pistillate*. In the ordinary commercial field approximately equal numbers of male and female plants occur. It is as important, therefore, to choose the best male plants as it is to select productive, healthy, and desirable types of female plants.

The improvement of asparagus by seed selection is an attractive undertaking and will prove profitable if done properly. Several methods are suggested below:

(1) Records of the performance of certain promising individual crowns should be kept over a period of several years. The crowns of the most desirable male and female plants should be dug and set together in a bed that is isolated. One male plant to about five or

six females is sufficient. It is best to group the female plants about the male. The desirable female plants will be pollinated only by the selected males. The resulting seed may be planted and the qualities of the progeny tested.

(2) In the commercial field, a number of the most desirable male and female individual plants should be marked in the ratio of approximately one male to five or six females. These individuals should be fairly close together in order that pollen may be carried from the male plants to the female plants. These marked individuals should be allowed to mature before the main crop, so that pollination is only between the individuals selected. The seed should be harvested and the progeny tested.

(3) A small isolated acreage should be set aside for seed production only. At the beginning of blooming time the grower should grub out weak and undesirable types of male plants. If they are left in the field, pollen from them may be carried to the flowers of the selected female plants and the undesirable characters of the inferior males will be transmitted to the progeny of the superior females. Seed from only the superior females should be harvested. It is unnecessary to grub out the inferior females, the seed of which should not be harvested.

Both male and female plants for seed production should be selected only from those whose stalks are uniformly tall and about one inch in diameter, and whose branches do not start close to the ground. Low branching is correlated with an early opening of the tips in the marketable sprouts.

*Harvesting and Grading Seed.*—If the berries are harvested before they are mature, the seed will shrivel to some extent. At maturity the selected seed-bearing plants are cut and laid on canvas, and the berries removed by stripping by hand, by beating, or by rolling. The berries may be placed in burlap sacks and pounded or tramped in order to break the berry coats and free the seed. This mass of material is then placed in a barrel or tank of water and stirred well. The seeds will settle to the bottom, and the lighter material, such as skins, pulp, and stems, will arise to the surface and can be skimmed or floated off. After several changes of water the seed should be spread out on a canvas to dry.

After the seed is dried, it should be run over properly meshed screens and graded as to size. The practice of grading is strongly recommended.

There is considerable variation in the weight and number of seed to the pound in different lots of commercial asparagus seed. Certain lots of seed have come to our attention which contain as many as 28,000 to the pound, and others which have approximately 19,000 seeds to the pound. The average run of commercial asparagus seed, however, has about 22,000. It is well known that Mary Washington seeds are of larger size and weight than those of any other variety. These qualities result in vigorous seedling development and large one-year-old crowns. There are a number of factors which influence the size of seed. Almost every lot of seed may be improved, however, by careful grading.

### SEED TREATMENT

Under average field conditions asparagus seed germinates slowly. It is usually from two to six weeks before the plants appear above the ground. This difference depends upon the temperature and moisture of the soil and the depth of planting. It is usually a week or more longer before the young plants are large enough to be visible in the rows and to permit cultivation. As a result of this slowness of germination and the inconspicuousness of the young plants, a growth of weeds may obscure the rows, and thus make cultivation and weeding a difficult and expensive operation.

Two methods have been used to overcome the difficulties in the asparagus nursery incident to the slow germination of the seeds. These are: (1) The sowing of quick germinating seeds such as those of radishes with the asparagus seed. The radish plants soon appear above the ground and the rows are thus marked so that the grower is better able to cultivate between them. (2) Soaking the asparagus seed in water to hasten germination.

The first method has not been practiced in the large nurseries of California. Soaking the seed before planting, however, is practiced by a number of growers. They assert that the plants come up a week or more ahead of those from unsoaked seed. Other growers maintain that they can see no difference in the rate of germination of soaked and unsoaked seed.

Prior to the work of Borthwick,\* of the California Experiment Station, there had been no carefully controlled experiments to determine the influence of various treatments upon the germination of asparagus seed. Borthwick conducted tests both in the laboratory

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\* Borthwick, H. A. Factors Influencing the Rate of Germination of the Seeds of *Asparagus officinalis*. Univ. of Calif. Publications, Agri. Exp. Station, Technical Paper No. 18, Nov., 1924.

and in the field, repeating his experiments a number of times. The various methods which were employed with a view of hastening the germination of the seed were abrasion, and soaking in acids, alkalies, various salt solutions, and water at different temperatures and for different lengths of time. The only method which gave definite and practical results was that of soaking in water.

In the laboratory tests, asparagus seeds were soaked at various temperatures from 71° to 122° F., and for different periods of time, ranging from 6 to 110 hours.

The seeds may be soaked for a period of at least nine days without danger of a reduction of final germination if the temperature does not exceed 104° F.

The quickest germination obtained in the laboratory followed soaking for 4½ days at 86° F.

Borthwick also made a number of field tests to compare with the results obtained in the laboratory. In one series of these tests he noted that sixteen days after planting, all lots except those soaked at 113° F. for 86 and 110 hours, had a higher percentage of seedlings above ground than the unsoaked control. Seeds soaked for 86 hours at 86° F. had practically as many seedlings above ground at the end of 14 days as the unsoaked seed had at the end of 21 days. Under the conditions of this experiment, the most rapid germinations occurred in seeds soaked in water for 86 hours at 86° F. and 62 hours at 100° F.

In another field test, the seed of which was planted in much colder soil than that of the preceding, it was found that in several soaked cultures, the number of sprouts above ground on the thirty-third day after sowing exceeded that of the unsoaked control on the fortieth day. Twenty-one out of 25 soaked cultures germinated sooner than the controls. Moreover, the final germination of a large number of soaked cultures as recorded on the fifty-first day, exceeded that of the controls. In this test the most rapid germination occurred in seeds soaked at temperatures of 86° F. and 95° F. for 96 hours.

There is a lack of uniformity in germination results in the field, as compared with results in the laboratory. This is due chiefly to differences in depth of planting and in soil moisture.

Borthwick shows also that previous soaking at the higher temperatures increases the rate of germination even if the seed is planted in cold soil. For example, seeds which had been soaked at 86° F. germinated more rapidly than seeds soaked at 68° F., even though both lots were germinated at 68° F.

In conclusion, it should be stated that soaking asparagus seed in water for the purpose of hastening germination will be of value only when the treated seed can be planted in moist soil. If placed in dry soil, and left there for even a day before water is brought to it either by rain or irrigation, the seed will lose water to the soil.

Soaking asparagus seed in water is not difficult. The temperature and time may vary considerably without danger of injury. A temperature of 86° F. to 95° F. for 4-5 days is recommended. Soaking in water at the ordinary temperatures of the air (70°-75° F.) for short periods of time has comparatively little value.

After the seed is removed from the water, it should be spread out thin on a canvas, moved about for a few minutes until the water disappears from the surface, and then planted immediately. The soaked seed will be hard and firm, and after drying for a few minutes, may be planted with a drill, or by hand. If the seed is dropped by hand in the furrows, moist dirt should be drawn over it and firmed immediately.

#### PLANTING SEASON

Early planting of seed is advised in order that the plant may have a long growing season during which to develop a large crown. The date of planting, however, must be governed largely by local and seasonal conditions. On the peat lands of the Delta region, seed can be sown in late February or March. In the Imperial Valley seeding can take place somewhat earlier.

#### VARIETIES

The varieties which are giving the most satisfactory results in California, regardless of whether the crop is to be marketed fresh or to be sold to the cannery, are Palmetto and Mary Washington. The latter variety has been bred to a high state of perfection, and the shoots are larger on the average than those of any other variety grown under similar conditions. The shoots are green with a purple tinge. The buds and leaf scales remain tight against the shoot for a considerable time, making it an ideal variety for the "green grass" market. The branches of the mature plant spread less than those of other varieties; the main stem grows very tall and in time bends over, giving a plantation of mature plants of Mary Washington a decidedly different appearance from that of other common varieties like the Palmetto, Argenteuil, and Conover's Colossal. Mary Washington is not entirely rust resistant, though it suffers less in severe epidemics of rust than the semi-resistant varieties such as Palmetto and Argenteuil.

### SEEDING

*Rate of Seeding.*—The tendency among growers in California has been to sow the seed too thick. It is not uncommon to plant as much as 20 pounds of seeds to the acre. It is doubtful whether more than 10 pounds is ever advisable. Where hand cultivation is to be practiced seed should be sown in rows 15–18 inches apart. Where horse cultivation is to be practiced usually a greater distance between the rows is necessary. It is best to drop seeds one in a place so that the plants will stand about three inches apart in the row. If the seeds are dropped in groups of three or four, fleshy roots and rootstocks become so interwoven that it is difficult to separate them at sorting time. The most expensive single operation in connection with the present method of producing crowns is that of separating the different individuals after digging. This expense can be greatly reduced by thinner seeding. Much injury is often done to the crowns in separating them when they are grown in thickly matted rows.

*Methods of Planting.*—The seeding is usually done with garden drills, although the seed is sometimes dropped by hand. When large acreages are planted, the drills are arranged in gangs, and two, three, or four rows are sown simultaneously. A number of growers in recent years have adopted the method of sowing the seed in furrows 3 to 6 inches wide in order to give the growing plants plenty of room to develop and still produce a large number of crowns to the acre. This method is better than planting too thick in narrow rows, but it is unsatisfactory on foul land, as a great deal of hand work is necessary to keep the rows free from weeds.

Where surface irrigation is practiced, the seed is usually sown on ridges or beds, similar to those used in the growing of lettuce. If the spring rainfall is plentiful the seed can be sown on the level, as the plants will be large enough for furrowing between the rows by the time irrigation is necessary. It is best to sow on the level or on low beds in those regions where strong drying winds are prevalent.

*Intercropping.*—Companion planting and intercropping are often practiced in the production of nursery stock. Good crowns can be produced in young orchards where plenty of sunlight is available, but the young asparagus plants will not do well in the older orchards where there is too much shade. (See fig. 12.) Some growers raise nursery stock between the asparagus rows that have just been set in the permanent field. This is undoubtedly an undesirable practice, especially from the standpoint of the permanent bed. The seedlings

rob the soil of plant food that is needed to establish the transplanted crowns. Moreover, the volunteer crowns which remain after digging are rather hard to eradicate for a year or two.

*Depth of Planting.*—The proper depth of planting varies with the type of soil. In peat soils the seed can be planted 2½ to 3 inches deep. There is little advantage in deep planting except to keep the seed in contact with a permanent moisture supply and thereby insure quick germination. In sandy loam and light sandy soils the seed should be planted from 1½ to 2 inches deep.

GERMINATION OF SEEDS

*Description of Berry and Seed.*—The asparagus berry usually has three seed cavities. As a rule two seeds begin to develop in each cavity, and if all attain maturity, the ripe berry will have six seeds. The actual condition, as ascertained by counting the seeds in all the berries of an average plant, is shown in the following brief table.

Number of seeds to the berry	1	2	3	4	5	6	7	8	Total
Number of berries.....	86	83	185	265	362	365	3	1	1,350
Per cent total number of berries. ....	6.3	6.1	13.8	19.7	26.8	27.0	0.2	0.1	100

From this it will be seen that there is approximately an equal percentage of berries containing five or six seeds, respectively. And, considering all the classes, the total percentage of berries having fewer than six seeds is much greater (72.7 per cent) than that having six seeds to the berry (27.0 per cent). A great number of seeds fail to attain maturity for one reason or another; and an examination of mature berries often reveals the presence of abortive seeds. One frequently finds plants bearing a number of prematurely red berries which are much undersized and contain no viable seed.

In any lot of asparagus seeds, it will be observed that there are two quite distinct shapes, as shown in figure 1. If two seeds develop in a single cavity, the surfaces which touch become flattened because of pressure. However, if but a single seed develops in a seed cavity, and consequently is not crowded, it becomes equally rounded on all sides. There is no reason to believe that one type of seed is superior to the other.

The asparagus seed has three essential parts:

- (1) The seed coat.
- (2) The embryo plant or germ.
- (3) The endosperm or reserve food.

The relationship of these parts is shown in figure 2. The seed coat consists of several layers of cells, the outermost of which has a very thick black wall which is distinctly roughened. This roughness can be easily seen with a hand lens. A conspicuous membrane composed of two fatty membranes close together (fig. 3) forms the inner boundary of the seed coat. This membrane plays a very important part in the absorption processes carried on by the seed. It has properties which enable it to prevent, either totally or in part, the entrance of certain salts and other substances, although it does not inhibit the movement of water through it.

The embryo plant or germ is a very small slender body, somewhat curved at one end. In the mature asparagus seed, the embryo is very simple in structure, and apparently has not attained a stage of development as advanced as that reached by the embryos of wheat, corn, bean, and many other plants when their seeds are fully mature. At one end of the embryo is the root tip. A short distance behind the root tip is a shallow depression, at the base of which is the growing point of the stem. The remainder of the embryo, and by far the largest part, is an absorptive organ. This organ remains in contact with the endosperm during the early stages of germination, absorbs food from the endosperm and delivers it to the growing root tip and stem tip. The comparative slowness of germination of asparagus seed may be due in part to the undeveloped condition of the embryo in the mature seed.

The embryo is completely embedded in the endosperm. The ends of the embryo, however, have very little endosperm tissue between them and the seed coats. The hard flinty endosperm constitutes a reserve food supply. There are two kinds of food stored in the endosperm of asparagus. These are *hemi-cellulose* and *fat*. Hemi-cellulose is a carbohydrate resembling somewhat, in its chemical composition, starch and ordinary cellulose. Hemi-cellulose is stored in the walls of the endosperm; fat occurs as droplets in the cell cavities. The hardness of the endosperm of the asparagus seed is due to hemi-cellulose in its walls. (See fig. 3.)

*Germination Processes.*—When the seed is placed under conditions favorable to germination, and sufficient water has been absorbed, digestion of the endosperm begins. In this process, hemi-cellulose



Fig. 1.—Two shapes of asparagus seeds (top view). Left, rounded seed from locule which bore but this one seed; right, seed flattened on one side, from locule which produced two seeds. *a*, flattened surface.

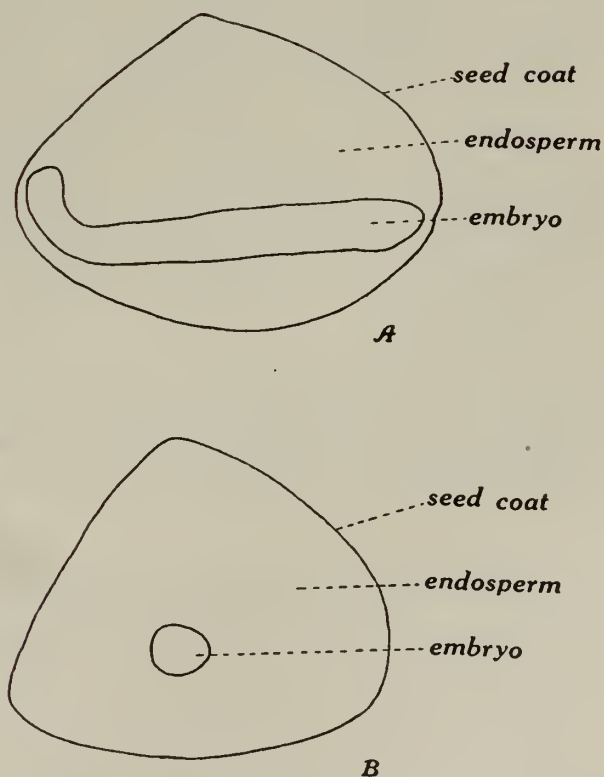


Fig. 2.—Diagrams of asparagus seeds showing position of the embryo.  
*A*. Section through the seed showing the embryo in longitudinal section.  
*B*. Section through the seed showing the embryo in transverse section.

and fat are changed chemically into substances which can move from one part of the seed to another. These products of digestion of hemi-cellulose and fat move to the root tip and stem tip of the embryo, and growth begins. The root of the embryo enlarges and after a time breaks through the seed coat. After it has attained a length of from one-fourth to one-half an inch, the stem or first shoot appears. The absorptive organ of the embryo remains in contact with the endosperm for several weeks, and during the absorption of the endosperm

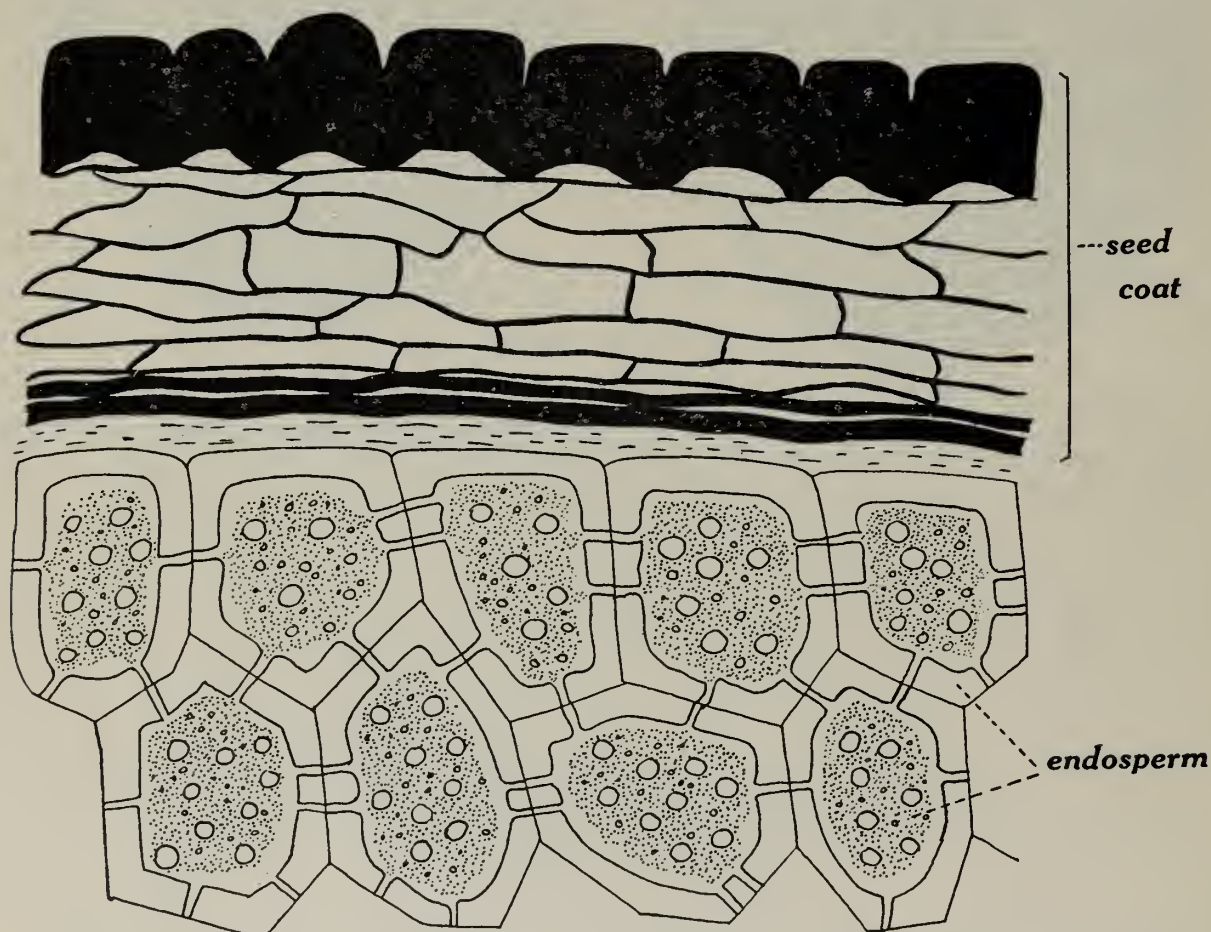


Fig. 3.—Section of a portion of an asparagus seed, showing the seed coat and the large cells of the endosperm, with thick walls of hemi-cellulose (“reserve cellulose”), and cell cavities filled with oil globules and protein granules. (Treated 18 hours with 2 per cent sodium hydroxide solution in order to swell the cells of the seed coat.)

it increases in size, finally becoming a large spongy structure, which may almost completely fill the seed. There is sufficient reserve food in the asparagus seed to supply the young developing plant for an extended period. It would not be possible to plant asparagus seed at the usual depth of 2 to 3 inches, if it were not for the large amounts of stored food in the endosperm, and the maintenance of a connection between this endosperm and the growing points of the embryo by the special absorption organ. The first shoot of the asparagus seedling receives nourishment from the seed sufficient to enable it to grow

through from 3 to 5 inches of soil. The growth of the primary root also depends for a considerable length of time upon the supply of food in the endosperm.

*Conditions Necessary for Germination.*—The requirements for the germination of asparagus seed, and in fact of all seeds, are water, oxygen, and a proper temperature. In certain experiments, asparagus seeds have been kept in water for three months without showing evidence of germination. However, this prolonged soaking in water at ordinary temperatures does no apparent injury to the seeds, for when they are removed from the water and placed under conditions suitable for germination, vigorous sprouts appear within a few days and the percentage of germination is normal. Asparagus seeds submerged in water may be made to germinate within 4 or 5 days, if the water is aerated by air bubbling through it. The above experiments point to the conclusions that asparagus seed will endure long soaking in water at ordinary temperatures, which means that asparagus seed in the field will withstand submergence in water or saturated soil for a long period—at least three months. However, germination of the seed will not result unless there is a plentiful supply of oxygen, such as occurs in a soil in good physical condition.

The optimum temperature for the germination of asparagus seed is between 77° and 86° F. At 68° F. germination is very slow. The rate of germination of asparagus seed at various temperatures is shown in table 1. (See fig. 4.)

TABLE 1

RATE OF GERMINATION OF UNTREATED ASPARAGUS SEED UNDER CONTROLLED TEMPERATURES IN THE LABORATORY

Temperature germinating chamber Degrees F.	Per cent germination after:							
	3 days	4 days	5 days	6 days	8 days	10 days	12 days	17 days
50	0	0	0	0	0	0	0	0
68	0	0	2	4	11	14	.....	27
77	0	25	65	84	98	.....	.....	.....
86	0	50	74	83	91	.....	.....	.....
95	0	5	.....	16	31	55	67	.....
104	0	0	0	0	0	.....	0	0

Asparagus seed will make slow progress if sown in a soil the temperature of which is near 68° F. or below.

The absorption of water by the seed at temperatures below 77° F. is very slow, as is seen from tables 2 and 3.

TABLE 2

RATE OF WATER INTAKE BY ASPARAGUS SEEDS SOAKED AT DIFFERENT TEMPERATURES  
(Percentage increase in weight is based on the original air dry weight.)

Temperature at which seeds were soaked Degrees F.	Percentage increase in weight when soaked:					
	4 hours	10 hours	15 hours	16 hours	22 hours	24 hours
50			11.7			14.4
64	6.1	14.4	.....	19.6	24.0	.....
72	6.1	15.8	.....	21.2	27.0	.....
86	15.9	27.5	.....	33.0	36.0	.....
104	27.6	36.5	.....	38.4	38.9	.....

TABLE 3

RATE OF WATER INTAKE BY ASPARAGUS SEEDS SOAKED AT TEMPERATURES OF  
64° F. AND 86° F.  
(Percentage increase in weight is based on the original air dry weight.)

Tempera- ture at which seeds were soaked Degrees F.	Percentage increase in weight after soaking:											
	3 hours	9 hours	24 hours	33 hours	48 hours	54 hours	69 hours	93 hours	117 hours	142 hours	153 hours	164 hours
64	5.4	13.2	28.7	34.5	40.2	41.1	42.6	43.2	43.3	.....	43.6	43.5
86	9.6	22.4	38.7	41.6	42.4	42.7	42.6	42.8	42.9	43.4	43.2	43.2

*Rate of Germination.*—The rate of germination of asparagus seed depends upon water and oxygen supply and upon the soil temperature. With all conditions near the optimum, the root breaks through the seed coat within 6 to 8 days after planting and within 10 or 12 days, the first shoot appears. The time required for the shoot to reach the surface of the soil depends not only upon the supply of water and oxygen, and upon the temperature, but also upon the depth of planting and the texture of the soil. The sooner the shoot reaches the light, becomes green, and begins to manufacture its own food, the greater are its chances of survival. If, however, the developing seedling must struggle through an excessive depth of soil, or one in bad physical condition, it may exhaust its food supply and succumb before reaching the surface.



Fig. 4.—Showing influence of temperature upon the rate of germination of asparagus seed. A, seeds germinated at 68° F.; B, 86° F. The photographs were taken seven days after placing the seed in the germinating oven. Forty-eight per cent of the seeds germinated at 68°, while 92 per cent germinated at 86°, within the week's time.

DEVELOPMENT OF THE PLANT DURING FIRST SEASON OF GROWTH

In the growth of the seedling the single, primary root takes a direct course downward, developing numerous thread-like lateral rootlets. The chief function of this primary root with its laterals is absorption. It seldom attains a length of more than 5 or 6 inches. It is much more slender and fibrous than the storage roots which develop later. The single primary shoot takes a direct course upward, and upon reaching the light, develops a few side branches and leaves. This primary shoot seldom attains a length of more than 4 or 5 inches. Both the primary root and the primary shoot are temporary organs. They wither and die long before the end of the growing season.

The developing plant maintains its connection with the reserve food supply in the seed for a long period, by means of its fleshy absorptive organ. The primary root and primary shoot attain a length of 3 to 4 inches before connection with the reserve supply of food in the seed is severed. On the very young crown, a brown scar may be observed at the point where the absorbing organ was attached.

Table 4 and figs. 5 to 8, inclusive, show the method of development of asparagus plants during the first season of growth. The plants studied were grown in a nursery on the University Farm at Davis. The numerical values are the average of twenty plants taken at random from the nursery on each date. Throughout the season there was a rapid increase in the number of storage roots, but a less rapid increase in the number of secondary shoots. By the end of July, both the primary shoot and the primary root had ceased to function.

TABLE 4  
DEVELOPMENT OF ASPARAGUS PLANT DURING FIRST SEASON  
(Numerical values are the average of twenty plants.)  
(Seeds planted March 24, 1923.)

Date of observation	Length of primary shoot above the seed (inches)	Length of primary root (inches)	Number storage roots	Maximum length storage roots (inches)	Number secondary shoots	Maximum length secondary shoots (inches)
April 27.....	3.0	4.1	0	0	0	0
May 19.....	3.8	5.1	1.6	0.2	1.2	1.1
June 9.....	4.0	5.2	4.1	5.5	2.1	5.7
June 30.....	4.2	5.4	6.4	7.5	3.7	7.6
July 24.....	4.3	5.4	16.1	18.6	5.5	12.1
August 13.....	.....*	.....*	28.3	.....	8.1	20.2
September 20.....	.....*	.....*	42.0	.....	9.0	24.0

\* Primary shoot and primary root withered. The seedling was attached to the endosperm on April 27, but on all subsequent dates it was free from the endosperm.



Fig. 5.—Five stages in the development of an asparagus seedling. At the left a very young stage showing the short seminal root and the much shorter seminal shoot, both of which are attached to the seed and are deriving nourishment from the stored food in the endosperm. In the second and third stages the seed is still attached. In the fourth stage the plant has become independent of stored food in the seed, the seminal shoot has branched slightly, a second shoot has arisen from the crown, and a fleshy root has developed. In the fifth stage there is shown the seminal shoot, two well developed secondary shoots and one very short secondary shoot. The following are the dates of digging and the ages of the different seedlings: (1) April 3, ten days after planting the seed; (2) April 7, fourteen days after planting the seed; (3) April 27, thirty-four days after planting the seed; (4) May 19, fifty-four days after planting the seed; (5) June 9, seventy-five days after planting the seed.



Fig. 6.—Asparagus plant dug June 30, ninety-six days after planting the seed. The slender seminal root may be distinguished from the more fleshy storage roots. The seminal shoot is seen at the left.



Fig. 7.—Asparagus plant taken from the nursery July 24, one hundred and twenty days after planting the seed. Note the small seminal shoot at the left. Compare with Fig. 6.

Each new shoot which arises on the crown during the first year is almost always larger than the one preceding. This condition is shown in the following measurements of the lengths of shoots appearing successively on two representative plants. It may also be seen in figures 5 to 8, inclusive.

PLANT No. I.

Order of development of shoot	Length when mature, in inches	Diameter at base, in inches
Primary shoot.....	5	withered
First secondary shoot.....	8.2	.08
Second secondary shoot.....	9.0	.10
Third secondary shoot.....	13.4	.10
Fourth secondary shoot.....	19.7	.16
Fifth secondary shoot.....	19.7	.16
Sixth secondary shoot.....	25.2	.19
Seventh secondary shoot.....	28.0	.23

The eighth and ninth secondary shoots at the time this record was made were just through the ground. The seventh secondary shoot was the first to produce flowers.

PLANT No. II.

Order of development of shoot	Length when mature, in inches	Diameter at base, in inches
Primary shoot.....	5	.08 (withered)
First secondary shoot.....	6.6	.10
Second secondary shoot.....	14.0	.10
Third secondary shoot.....	16.5	.10
Fourth secondary shoot.....	24.4	.16
Fifth secondary shoot.....	25.2	.16
Sixth secondary shoot.....	26.7	.16
Seventh secondary shoot.....	11.8 (immature)	.16

The seventh shoot was the first to produce flowers.

This larger size of the new shoots which appear successively on the lengthening rootstock is probably due to the rapid increase in the supply of food.

The rate of development of the nursery asparagus plant, through the stages just described, depends much upon soil conditions, particularly upon the available water supply. The plants are very responsive to soil moisture variations. (See figs. 12 and 13.) New shoots and new roots develop in rapid succession if there is an adequate water supply. Any deficiency in the available water, however, is readily reflected in retarded growth of the plants. By the last of June the roots in the plants to which table 4 refers had penetrated the soil to a depth of 7 inches or a little more, and by the last of July they had reached levels as deep as 18 inches.



Fig. 8.—Asparagus plant taken from the nursery August 13, one hundred and forty days after planting the seed. Note the first flower-bearing stalk (center). The seminal root has become detached and the primary shoot has withered. This plant shows very strikingly the increase in height and diameter of the shoots as they make their appearance consecutively throughout the season.

## SEX EXPRESSION IN THE NURSERY

Under California conditions asparagus comes into flower during the first season of growth from seed. It is often possible, even in the nursery before the flowers appear, to distinguish male from female plants. The latter are taller, as a rule, than the former but the number of shoots to the plant may be fewer. Male plants bloom earlier in the season than female plants. Considering the population as a whole in the early season, the male individuals constitute a majority of all plants in bloom. This is shown in the following table, the data of which were taken in the asparagus nursery at the University Farm, at Davis.

TABLE 5

NUMBER OF MALE AND FEMALE PLANTS IN BLOOM ON DATES INDICATED

Date	Number of plants observed	Number of male plants	Number of female plants	Number of plants without blossoms
July 2.....	3,200	22	0	3,178
July 7.....	4,200	31	0	4,169
July 11.....	800	18	0	782
July 13.....	5,700	202	0	5,498
July 16.....	9,200	214	1	8,985
August 8.....	800	89	11	700
August 10.....	800	60	50	690
August 11.....	400	26	24	350

As the season advances, the percentage of pistillate plants in bloom increases.

## THINNING

It is doubtful whether thinning is practicable. Seeding should be regulated so as to get the desired stand without thinning. The method of plant development makes the thinning process very difficult. This operation must be performed before the second aerial shoot has appeared and before the development of the fleshy root system has begun. After the fleshy root system has begun to develop, the shoot usually breaks off at the crown when an attempt is made to pull the plant. If the crown remains in the soil, shoots again appear in a few days. After the fleshy roots have once started to develop the only way to thin is to dig out the crown, but in doing this there is danger of injuring adjacent plants.



Fig. 9.—Crown of asparagus plant, taken September 20, one hundred and seventy-eight days after planting the seed. From table 4, it will be seen that from August 13 to September 20 the plant produced but a single secondary shoot. There was, nevertheless, a considerable increase in the number of storage roots and in the size of the crown.



Fig. 10.—Asparagus nursery near the end of the growing season. The plants are properly spaced, and an excellent growth has been obtained.

### IRRIGATION

The soil about the developing rootstock and fleshy (storage) roots must be kept moist if the best development is to be obtained. The fleshy roots will not elongate in dry soil. Fleshy roots that have started to grow in moist soil, stop elongating when the soil becomes dry. Crowns which have a large number of short fleshy roots have usually been subjected to periods of drought. The entire soil zone occupied by the fleshy roots and rootstocks must be kept moist if the maximum growth is to be obtained the first year. Water should not be added, however, after the early part of September. If the soil is



Fig. 11.—Showing one method of surface irrigation of asparagus nursery. The rows of plants are level with the surface, and are two feet apart.

kept moist, new shoots continue to appear as long as the temperatures are sufficiently high for growth to take place. Shoots appearing late in the fall make a considerable demand upon the stored food in the crown.

### CULTIVATION

The manner of cultivation should vary with the type of soil and the method of planting. In weedy fields cultivation is often necessary before the seedlings appear above the ground. If a little radish seed has been drilled in with the asparagus seed the rows can be seen within three or four days. Cultivation may be started as soon as the rows are visible. Hand cultivation with a wheel hoe is usually prac-

tised where the rows are close together. Where surface irrigation is practiced it is necessary to cultivate the ground after each irrigation just as soon as the soil can be worked. In case of horse cultivation, care must be taken not to injure the fleshy roots and rootstocks by plowing too deeply or too near the row, especially late in the season after the roots have spread through the soil surface. The roots spread from the rootstock in the shape of a cone. They are nearest the surface where they are attached to the rootstock.



Fig. 12.—Asparagus nursery in a young pear orchard. There are six rows of asparagus between each two rows of trees. The picture also shows the influence of the water supply upon the growth of asparagus plants. The large plants occupy a strip of soil which allows water to seep through it more readily than other portions of the orchard.

#### DIGGING THE CROWNS

Crowns are usually plowed out during the late fall or early winter. The tops should be cut with a mowing machine and then raked and burned so they will not interfere with the digging operation. The crowns can be turned out with a two-horse mold board plow. Another implement that has proved very satisfactory for loosening crowns in the nursery is a U-shaped knife that runs under the mass of fleshy

roots and straddles the row. The knife at the bottom should be 6 or 8 inches wide with an upward tilt toward the rear which will have a tendency to loosen the dirt about the crowns and make it easier to lift them from the soil. The latter method of digging is especially adapted to rows that are planted far apart, in which case a large part of the root system can be saved. Whenever possible, the fleshy roots should be obtained uninjured. If the growing point of the fleshy root is not injured it will continue to elongate after planting (fig. 14). The fleshy roots continue to grow and elongate year after year. They do not die back unless injured.



Fig. 13.—Asparagus nursery. Note the strip running through the center of the field, in which the plants are comparatively well-developed. The thin stands on either side are due to a water table permanently too high. This view and that in Fig. 12 emphasize the fact that asparagus plants are very sensitive to the supply of available moisture.

A short-handled six-tined manure fork may be used to lift the crowns out of the soil and shake out the loose dirt. The crowns are then thrown in windrows or small piles and allowed to dry for an hour or so before they are hauled from the field.

When hauled from the field the crowns should be placed on a dry board or cement floor or on well-drained ground. The best storage temperature is about 40° F. They can be stored for a long period at much higher temperatures if the atmosphere is dry. If the crowns



Fig. 14.—A vigorous “Number 1” asparagus crown, taken during the second season of growth. Note the injured root tips, which have made no further growth. Root tips which are uninjured in digging continue growth. The fresh white storage roots, from which arise numerous absorbing roots, stand out in contrast with the older and darker storage roots which bear fewer absorbing roots. At points marked “a” in the photograph, there can be seen the line of demarcation between two successive years’ growth of a storage root.

become moist from heating or from rain or heavy fogs they soon start to rot. Hundreds of thousands of crowns are lost each year because of rotting. The fleshy roots contain large amounts of cane sugar, which is an excellent medium for the growth of mold organisms. Mold spreads very rapidly in the presence of moisture and a high temperature, such as often exist when crowns are stored in large piles. The planting of crowns that have been stored in large piles and that have been injured by molding is one of the most common causes of poor stands in the field. The buds may be dead even though the fleshy roots appear sound and healthy. In more severe cases both the fleshy roots and the buds may be dead.

The crowns should not be stored where they are subject for a long period to desiccating winds. Though crowns will stand a great deal of drying, growth response is much more rapid when they are not subjected to extreme desiccation. The best results are obtained when the interval between digging and planting is short.

Some tests of crown desiccation were started at the University Farm in 1924 to determine how much growth was retarded when the crowns were dried for a considerable period. Table 6 shows the date of digging, the loss of weight during storage, and the stand at various dates after planting.

TABLE 6

DELAY OF GROWTH CAUSED BY ROOT DESICCATION (VARIETY, PALMETTO)

(Loss of weight in stored crowns.)

Row number	Crowns dug, date	Weight of crowns on 2/11/24, pounds	Weight of crowns on 3/27/24, pounds	Loss in weight, per cent	Set in field, date	Number of crowns having aerial shoots on:				
						5/2/24	5/7/24	5/12/24	5/20/24	8/8/24
25	2/5/25	52.00	41.21	20.7	3/29/24	1	16	55	94	118
55	2/5/25	47.00	38.25	16.49	3/29/24	6	26	47	93	118
85	2/5/25	49.00	39.50	20.60	3/29/24	2	8	36	79	118

Crowns were stored in burlap sacks in a dry room subject to the same temperature fluctuations as the outside atmosphere. There were 118 crowns in each sack, sufficient to plant one row. The crowns were set in the permanent bed March 29, 1924, after being exposed to desiccating conditions for a period of 53 days. They were planted in furrows eight inches deep and covered with about two inches of soil. Water was then run in the furrows over the crowns. At inter-

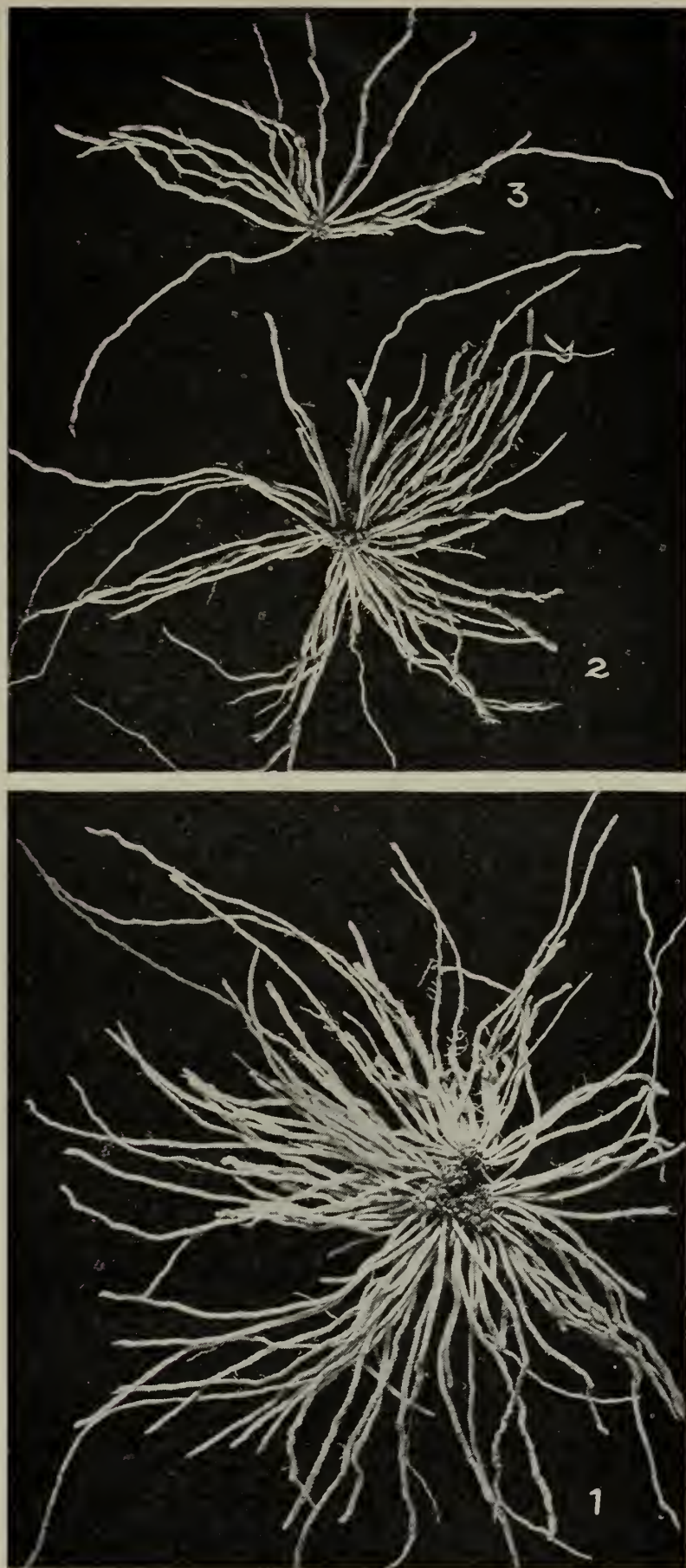


Fig. 15.—Grades of crowns: “Number 1,” “Number 2,” and “Number 3.” It should be the aim of the grower to produce “Number 1” crowns to plant in the permanent field.

vals a count was made of the crowns having aerial shoots. Table 6 shows that the starting of growth in the desiccated crowns is very slow. Even under the most ideal growing conditions it was 34 days before any shoots appeared above ground.

#### **SORTING AND GRADING CROWNS**

While in storage the crowns should be sorted and graded (fig. 15). The crowns are separated in order to facilitate planting. In the sorting, the small crowns should be discarded as well as large crowns that have a large number of small buds. Large crowns with a few buds are better than large crowns with a large number of small buds.

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